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GENERATION OF COHERENT VUV AND SOFT X-RAYS

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I. INTRODUCTION

The goal of this program is the generation of coherent extreme ultraviolet and soft x-ray coherent sources. The general method employed is optical nonlinear harmonic generation in gaseous media. There are basically two complementary approaches which can be used. The first is to utilize successive low-order processes, taking advantage of resonance enhancements to create large nonlinear coefficients. The second approach is to generate short wavelength radiation in a single high-order nonlinear stage, utilizing extremely high power densities to achieve observable signal levels. During the past period both of these approaches have been investigated, and our results are described in the following sections.

II. RESONANTLY ENHANCED HARMONIC GENERATION

The object of this experiment is to enhance the efficiency of a three photon sum process using the 2p-3p non-allowed transition in neon, which corresponds almost exactly to the sixteenth harmonic of Nd:YAG laser frequency. By adding two photons, whose sum energy equals this transition, plus another photon at 1.06 μ, a sum wavelength of 626 Å is produced. New[1] has shown that the third photon does not have to be applied synchronously with the first two; the first two photons produce a coherent excitation of the 3p level which persists for approximately 100 ps. The third photon may be applied anytime within this coherent lifetime. This result has two important consequences. First, it eases the experimental timing tolerances considerably. Secondly, such a delay can be used advantageously to increase the conversion efficiency. For example, if all of the photons are incident simultaneously, the power of the 1.06 μ radiation must be limited to approximately 5×10^9 W/cm^2 to avoid level shifts which would destroy the two photon resonance; however, if the 1.06 μ radiation is delayed, the resonance excitation of the 3p level has already been achieved, and the power density may be increased substantially. Using such a technique, New has predicted that efficiencies of several percent may be achieved.

Our original plan was to excite the neon 2p-3p transition using the eighth harmonic (1330 Å) of a Nd:YAG laser. A number of difficulties, however, prevented us from efficiently generating the eighth harmonic directly, and we redesigned the experiment to make use of the seventh, and the ninth harmonics, 1520 Å and 1182 Å respectively, to hit the resonance. Sources to generate these wavelengths at sufficiently high power were successfully constructed. We developed new techniques for monitoring and combining the two VUV beams; delay lines were constructed which selectively delayed the 1182 Å and 1520 Å signals from the other harmonics present. This was necessary in order to avoid gas breakdown by the higher power, lower order harmonics. A monitoring system was constructed which allowed us to confirm the excitation of the neon 3p state by observing the decay fluorescence at 6143 Å in the 3p to the 1s state. Following this development, several attempts were made to observe 626 Å radiation; all attempts were unsuccessful. We are still investigating the reasons for these failures. Probable causes include poor beam quality preventing the realization of the required high power densities, difficulties in overlapping the three input wavelengths in both time and space, and high losses in the monochromator resulting from oil contamination.

III. GENERATION OF VUV RADIATION USING HIGHER ORDER NONLINEARITIES

During this period Reintjes, et al.[2] reported the successful generation of 532 Å and 381 Å radiation as the fifth and seventh harmonic, respectively, of 2660 Å radiation using helium. Applied power densities of about 10^{15} W/cm^2 were used to achieve conversion efficiencies of approximately 10^{-6}. We have repeated and confirmed these results in our laboratory. In order to achieve such high power densities, however, a number of improvements in our laser system had to be made. Beam quality of the 2660 Å radiation was improved by using shorter doubling crystals, and the optical filtering system was carefully adjusted to avoid distortion of the beam profile. We developed a technique to directly measure the beam parameters at the focus based on the Focault knife-edge test. Focusing lenses were specially selected to avoid spherical aberrations, which in many cases severely reduce the obtainable power densities. A method of protecting the spectrometer gratings from the high incident power densities of 2660 Å was devised using thin aluminum filters. Incorporating these improvements we were able to generate 532 Å radiation at about 10^{-6} conversion efficiency; 381 Å radiation was also observed but at a signal-to-noise level of about one.

IV. FUTURE EFFORT

High order nonlinear processes at extremely high incident power densities have been used successfully to generate vacuum ultraviolet radiation; efficiencies, however, remain quite small. Thus the goal of this program continues to be the development of efficient, practical sources of vacuum ultraviolet radiation. During the coming period we will be evaluating a number of possible experimental approaches to this goal, including a continuation of our neon experiment.

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